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VOLATILE ORGANIC COMPOUNDS (VOCs) EMISSION FROM WOOD COATING

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INTRODUCTION

The finishing of wood surfaces with coating materials such as paint, wax or varnish is carried out with the objectives of obtaining the desired appearance and improving its life service time. However, most of the wood coating materials contain volatile organic compounds (VOCs) such as ethylbenzene, dichloromethane, benzene, etc. The emission of VOCs from wood coating materials can cause indoor air pollutant, resulting in major problems to the health, comfort and productivity of building occupants (Brown et al. 1994; Wilke et al. 2004; Kanazawa et al. 2010). Direct exposure to VOCs may cause chronic or acute effects on the respiratory and nervous system that lead asthma and even leukemia (Fan et al. 2012, Mitchell 2013). Therefore, understanding the properties of VOCs emitted from wood coating is important to help us in reducing health risk. This paper describes the VOCs in wood coating and addresses the precautionary actions that should be taken during the coating operation in workshops in order to reduce the risk of operators being exposed to VOCs. The methods used for the analysis of VOCs from wood-coated products are also discussed herein. This paper aims to provide better understanding regarding the VOCs emission from wood coating materials, the health risk of VOCs exposure, available techniques to determine VOCs and precautionary actions that can be taken during the coating operation.

VOCs IN COATING

The main composition of coatings consists of binders, solvents (volatile organic substances or water), additives and pigments (colorants and extenders). Solvent-based, volatile organic substances, also known as organic solvents contain VOCs such as benzene, ethylbenzene, toluene and xylene. These organic solvents are widely used by coating industry to produce solvent-based coating. According to American Coating Association, ACA (2017), the term volatile defines any chemical substances that would easily evaporate at a normal temperature while the term organic indicates that the chemicals are carbon based. Xu et al. (2016) defined VOCs as organic matters with boiling points below 250^{o}C at atmospheric pressure. Application of organic solvents in the coating creates fast-drying effect which allows the binders, additives and pigments to produce an excellent coat film to protect and enrich the transparency or colour or gloss of the wood surfaces. VOCs emissions occur during the drying process of coating. Figure 1 shows different solvent-based coatings available in the market.

Figure 1 Examples of solvent-based coatings available in the market

PARAMETERS THAT AFFECT VOCs EMISSION RATE

The rate of VOCs emission to the environment can be related to the temperature and humidity of the surroundings. Wolkoff (1998) measured the emission of VOCs of floor varnish and wall paint in the laboratory emission cell (FLEC) and field up to 250 days, and investigated the influence of temperature, relative humidity and air velocity at the different VOCs emission stages. Kim et al. (2010) reported that the VOCs emissions of paint were stable after at least 7 days under 24 hours curing condition. Stockwell et al. (2021) indicated that the emission of VOCs can vary significantly due to factors including drying time, temperature, humidity, and substrate interaction or properties. According to Kozicki & Guzik (2021), a relationship between temperature and rate of emission can be seen when the thermal movement of molecules intensifies and accelerates the diffusion resulting in a higher emission rate as the temperature increases.

VOCs PENETRATION INTO HUMAN BODY

Once the organic solvent in coating evaporated, it would discharge VOCs into the surroundings that can affect the human health (Minnesota Department of Health 2021). VOCs can penetrate into human body through either ingestion, dermal absorption or inhalation (Anand et al. 2014). Ingestion occurs when materials that have VOCs content are eaten or placed in the mouth. Children and baby are the vulnerable group to VOCs via ingestion. Dermal absorption occurs when VOCs come into contact with the skin (Wolkoff et al. 2006; Bernstein et al. 2008; Batterman et al. 2014). However, the easiest way VOCs penetrate into our body is through the air that we breathe (inhale) in our homes, offices, schools and other indoor environments, which finally will enter our blood system (Moro et al. 2012; Duan et al. 2016). The coating operators are having the highest tendency of being exposed to VOCs through breathing.

EFFECT OF VOCs EMISSION

Most of the VOCs are toxic and affect the human health. Some of them such as benzene can contribute to an increased lifetime of cancer risk (Guo et al. 2004). In contrast, some of VOCs do not cause cancer risk, but can cause health hazard such as eye irritation and chronic or acute effect to the respiratory system (Wolkoff & Nielsen 2010; Wu et al. 2012). Wang

et al. (2017) reported that inhaling formaldehyde can cause irritation of the eyes and upper respiratory track; benzene causes acute leukaemia, while toluene is well recognized to be toxic to the neural and reproductive system. The health effects due to VOCs depend on the type of chemicals, concentration of chemicals (amount) and the duration a person breathes them (EPA. 1991; Kostyko & Wargocki 2012). Table 1 summarizes the effect of short-term and long-term exposure to VOCs.

Table 1 Effect of VOC to human health

Acute/short term exposures (hours to days)	Long term exposures (years to a lifetime)
1. Eye, nose and throat irritation	1. Cancer
2. Headaches	2. Liver & kidney damage
3. Nausea/vomiting	3. Central nervous system damage
4. Dizziness	
5. Worsening of asthma symptoms	

Source: Minnesota Department of Health (2021)

THE NEEDS OF VOCs EMISSION ASSESSMENT

Considering that VOCs emission can cause negative effects towards human health, therefore indoor air quality is a growing concern recently (Liu et al. 2019). A lot of green building standard and certification systems are developed worldwide in response to growing concerns for products toxicity, human health and indoor environment. Legislation such as the Solvents Emission Directive emphasises on the VOCs content of coating, and it is prescriptive on the amount of organic solvent that can be released to the indoor environment. Therefore, determination of VOCs is an essential for coating-based products and coating operations such as coating factories and workshops.

There are many available techniques to determine the emission of VOCs in coatings. According to Ohio Environmental Protection Agency (2014), VOCs released from coatings can be calculated using mass balance technique, i.e. by assuming that all of the VOCs contained in the liquid (volatile organic solvent) portion of the coating are emitted into the air after the coating is applied and dried. Moreover, additional of diluents, thinners or reducers to the coating will increase the VOCs content when the coating is applied on the wood surface. According to ISO 11890-2, gas chromatography is a useful technique for identifying each VOCs component in coatings and coated products. Test chamber method is another technique widely used to study the emission of VOCs. Guo & Murray (2000) investigated the time of VOCs emission from twelve paint products using a small test chamber.

PRECAUTIONARY ACTIONS DURING COATING PROCESS

There are two factors of concern regarding coatings, i.e. type of coatings and application process. Precautionary actions need to be taken to reduce VOCs hazards as follows:

Proper ventilation system

Vapour exposure risk from coating using spraying technique is the main concern due to high VOCs and small particles. Vapour from coating may cause short-term effects that include headaches, vomiting, dizziness etc. It also may cause long-term health effects such as asthma, damage to central nervous system and cancer. Therefore, well ventilation system is essential to reduce the VOCs risk.

Appropriate personnel protection equipment (PPE)

Wearing of personnel protection equipment (PPE) is essential to enhance the protection of operators during coating process. The correct personnel protective equipment is essential to avoid potential injuries especially when working with chemicals with a high toxicity for extended period. An undesirable health effects might result from improper protection.

Spray booth

The spraying process should be conducted in a spray booth where ventilation is available (Figure 2). This is important in order to prevent the concentration of flammable materials build-up in a restricted area. Figure 3 shows the correct personal protective equipment that an operator should be wearing during the coating operation.

Figure 2 Ventilation and spray booth

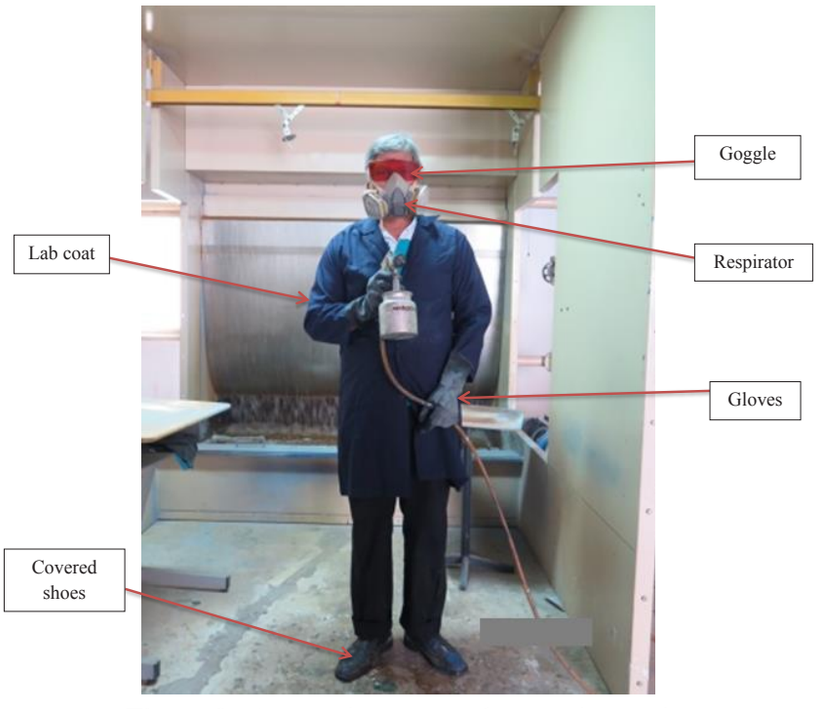

Figure 3 Appropriate personal protective equipment

ALTERNATIVE WAYS TO REDUCE VOCs FROM COATINGS

The level of VOCs emitted from finishing can be lowered where organic solvents can be replaced by water-borne coating or high-solids coating (Muller & Poth 2012). Water-borne coatings have low toxicity as they contain very less solvents, thus decreasing the VOCs output and making them more user-friendly (Stoye & Freitag 1998). Stoye & Freitag further added that water-borne coatings scale down the concentration of flammable materials that build up in a restricted space. In addition, they dry to crystal clear and preserve the wood's colour (Spagnuolo 2009).

According to Muller & Poth (2012), high solids coatings are formulated to have higher concentrations of solid components such as binders, pigments and additives. The solid contents of coatings are classified as shown in Table 2. Coatings with a high content of non-volatile matter would therefore have low content of organic solvents. Consequently, using high solids coating would greatly reduce the VOCs being released into the surroundings.

Table 2 Solid contents of coating

Coating type	Non-volatile matter [wt.%]
Low-solids	<30
Normal-solids	30 to 60
Medium-solids	60 to 70
High-solids	>70 (sometimes > 80)

CONCLUSION

Low-solids coating has higher level of organic solvents, thus it releases more volatile organic compounds (VOCs) into the surroundings which is harmful to human health. Nevertheless, the danger of health effects from exposing to VOCs actually depends on the amount and period of a person breathes it in. Several techniques can be used to determine the emission rates of VOCs including mass balance techniques or test chamber method. Most importantly, precautionary actions must be taken in order to avoid being exposed to high level of VOCs that would be carcinogenic to humans.

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This paper describes the volatile organic compounds (VOCs) in wood coatings and addresses the effects of the VOCs emission towards human health. The precautionary actions that should be taken during the coating operation in workshops are also discussed. The VOCs released from coatings can be calculated by using mass balance technique, gas chromatography or test chamber methods. The temperature and humidity of the surroundings are the parameters that affect the rate of VOCs emission. VOCs can penetrate into human body through ingestion, dermal absorption or inhalation. VOCs can increase cancer risk or other health hazards, depending on the type and concentration of chemicals, and also the duration a person breathe them. The replacement of organic solvent-based coating with water-borne coating or high solids coating can be the solution to reduce the emission of VOCs.

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